THE MANUFACTURE OF BASIC PIG IRON AND BASIC STEEL

Paper presented to the Institution, Luton Section, by J. A. Thornton, Esq.

The paper deals chiefly with the manufacture of basic steel. The various processes are described in detail, commencing with the manufacture of coke and the operation of blast furnaces. The basic open hearth method of steel manufacture incorporating both hot and cold metal practices are then described. Reference is made to the manufacture of "free cutting" steel.

THE manufacture of pig iron and steel commences with the extraction from the earth of the necessary minerals such as iron ore, limestone, dolomite, magnesite, fireclays, and coal. The operations of mining and quarrying are not within the scope of this paper, which can conveniently commence with the manufacture of coke for use in the blast furnace. Suitably blended coals possessing coking qualities are necessary for the manufacture of metallurgical coke. Such coke needs to be strong, tough, free from brittleness, and capable of supporting a tremendous load in the blast furnace. The coke is produced in ovens capable of holding a charge of anything from 10 to 20 tons. These ovens vary in width from 16 to 20 in., have a length of about 40 ft., and a height sufficient to leave room above the charge for the gases given off during the carbonising period. These gases are passed along to the bye-product plant, where valuable constituents are taken out.

The time taken to carbonise the coal from coke varies according to the quality of the coal, and the width of the oven. A usual value is one hour per 1 ft. width of oven. The oven proper is constructed of high grade silica brick, the supporting and upper brickwork being of high class fireclay.

After carbonising the oven is rammed by a powerful ram on to a travelling coke car, which conveys the coke to the quenching tower, and then to the coke bench, from which it is transported to the screens and the blast furnace bins.

There are several methods of heating coke ovens. The three principal ones are (1) using some of the gas produced during carbonisation, (2) by the use of blast furnace gas, and (3) by using a mixture of coke oven gas and blast furnace gas. With coal of about 30% volatile, approximately 11,000 cu. ft. of gas at a B.T.U. of 520/530 are produced per ton of coal carbonised. About 40 to 45%

of this gas may be taken back to the coke ovens themselves for heating purposes. There will also be produced approximately three to 4½ gallons of crude benzole 65%, about 25 to 27 lb. of neutral sulphate of ammonia, and about eight gallons of tar. With an approximately 13 ton charge of coal, it may be taken that roughly 100 tons of coke per oven per week will be produced, that is 50 ovens will produce 5,000 tons per week of 168 hours.

Blast Furnaces.

Iron ore in the raw state is the main material in the making of pig iron. This paper deals only with the manufacture of basic pig iron, although hematite, and various qualities of foundry iron, as well as ferro-manganese, ferro-silicon, etc., are also manufactured in the blast furnace. The analysis of good basic pig iron is .5 to .75% silicon, .04% sulphur, .75% phosphorus (although this may in some cases go up to 1.8%) and 1% to 1½% manganese. This being the basis, the furnace must be burdened to give iron of the foregoing analysis. Ores suitable for this class of iron are produced in large quantities in the Northamptonshire area, and to a smaller extent in the Cleveland Hills of North Yorkshire. Large supplies are also imported from Sweden, France, Spain, North Africa, and certain amounts from Brazil and Newfoundland. These ores vary in iron content from 26% to as much as 67 to 68%. It is a matter of interest to note that the higher grade Swedish ores with over 60% iron content can easily be handled by electromagnets.

It should be understood that some ores which are suitable for the production of basic pig iron are totally unsuitable for the manufacture of hematite iron, and certain classes of foundry iron. Hematite iron requires ores containing not more than about .02 phosphorus. It is well known that all the phosphorus in the ore presents itself in the final pig iron. Other constituents of the ore divide themselves between the pig iron and the resultant slag, which is formed in the process of reduction in the furnace, and is controllable.

Other materials needed for the production of pig iron are coke and lime stone. The coke is required to maintain the high temperature needed to reduce the ore. The lime stone acts as a flux. Last but not least of the materials which must be supplied to the blast furnace in order to produce pig iron is air. The weight of air required exceeds that of any other component of the charge.

The reactions inside the furnace are complicated, but they can be reduced in essence to the following comparatively simple terms. The hot blast at 1,000° to 1,600°F. enters the furnace through tuyeres at 5 lb. to 15 lb. per square inch, and meets the coke in front of the tuyeres. The oxygen of the air immediately unites with the carbon in the coke to form CO_2. This gas, however, is at once changed to CO by contact with the surrounding particles of

incandescent coke. The water vapour in the air is decomposed in contact with incandescent carbon, the oxygen uniting with the carbon and leaving hydrogen.

So we get three reactions: (1) Carbon burned to carbon dioxide $C - 2O = CO_2$; (2) reduction of carbon dioxide by hot coke $CO_2 - C = 2CO$; (3) incandescent carbon decomposing water and combining with oxygen $C - H_2O = CO - H_2$. The nitrogen of the air remains unchanged and merely dilutes the other gases. Air may be blown into the furnace either by reciprocating steam or gas engine blowers, but a popular modern method is to use turbo blowers. To obtain the above high temperature air, hot blast stoves are used.

The modern blast furnace from foundation to the top of the gas outlet will be approximately 200 ft. and will produce (according to the hearth diameter) anything from 300 to 1,200 tons per day, using coke at the rate of 15 to 18 cwts. per ton of basic pig iron made. Turbo-blowers capable of delivering from 20,000 to 80,000 cu. ft. of free air per minute at pressures up to 25 lb. per square inch are needed. For each ton of coke consumed the blast furnace yields approximately 140,000 cu. ft. of gas of about 100 B.T.U. per cubic foot, the analysis being 30% CO, 10% CO_2, and 60% nitrogen. Such gas is cleaned to a very high degree of fineness, and is used in the heating of the hot blast stoves and, as mentioned previously in the heating of coke ovens. In addition, this gas is suitable for use in internal combustion engines due to the absence of hydrogen, and also in the various furnace plants in and about an iron and steel works. The lining of a blast furnace is made of high class firebricks, having approximately 40% alumina, the remainder being nearly all silica.

Steel Manufacture.

The only difference between the basic and the acid process of making steel, so far as the furnace is concerned, is that the basic furnace has a basic lining composed of magnesite, dolamite, or both, whereas the acid furnance has a silica lining, and is bottomed with a high silicious sand, similar to that which is obtained in the Leighton Buzzard district. Good steel can only be made from specially selected materials if the acid process is used, whereas the basic open hearth furnace is so versatile that it can refine pig irons having a high phosphorous content, and produce steel equal to that produced in the acid furnace. It should be noted that about 80% of the steel manufactured in Great Britain is manufactured by the basic open hearth process. There are numerous methods of supplying gas to the furnace. The gas supplied to the furnace may be producer, coke oven, blast furnance, a mixture of the producer and coke oven, or a mixture of the coke oven and blast furnace.

The furnace has to be charged with suitable materials in order to produce the quality of steel required by the customer. In some furnaces cold metal practice is used in which the major portion of the charge may be scrap, and the remainder pig iron. In other furnaces hot metal practice is employed in which as much as 60 to 75% of the charge takes the form of molten pig iron, which is sent direct in the ladles from the blast furnace. The remaining 25 to 40% of the charge consists of scrap. Every furnace charge must contain a quantity of pig iron which will ensure a carbon content sufficient to maintain the intense heat required for the chemical reactions.

In addition to the metallic content of the charge, lime stone and/or lime is used for fluxing, and high grade ore, such as Swedish and mill scale, for oxidising the carbon and phosphorus in the pig iron and other iron scrap. In refining, slag is made. This slag is the principal guide whereby the operator ascertains the condition of his furnace bath.

When making ordinary carbon steels the adjustment to the carbon is usually made in the ladle during the tapping process, but other additions such as nickel, chrome, molybdenum, sulphur, etc., are added to the furnace before tapping. The steelmaker knows what alloys he will recover in his steel, and what his losses will be, and in designing his burden these losses have to be taken into account.

It is astounding to me that the steel maker is able to produce steel to the fine limits prescribed by the average metallurgist. The high price of steel is largely due to these fine limits, some of which are quite unnecessary. For instance, different motor car companies frequently demand different steels for manufacturing the same components. I venture to suggest that the steels used for similar motor car parts could be standardised, thereby cheapening production. Furthermore, I venture to suggest that a number of metallurgists could, with advantage explore the possibilities of an extended use of just carbon and manganese.

Another section of steel making which should be of interest to the production engineer is the manufacture of free cutting steel. The steel maker after having spent thousands of pounds in refining steel, is asked to degrade his product so that the machine tool can give a bigger output. Surely the right thing to do would be to impose on the manufacturer of tool steel the necessity to produce a steel which would fulfil the conditions required by the production engineer.

There are numerous views as to what should be the sulphur content in free cutting steel. I will now quote an extract from a paper of a one-time colleague of mine, who is now chief metallurgist of the Indian Iron and Steel Company: " . . . a fifth class with the

same carbon but with greatly increased sulphur and phosphorus (.1 to .15%) is that known as ' free-cutting.' The author has nothing to say in favour of these steels as a metallurgent. After refining the steel in the bath one proceeds to degrade it in the ladle by large additions of sulphide and phosphides of iron. It is difficult to roll and its mechanical properties are impaired. It does, of course, allow very rapid machining on automatic lathes and gives a very ' fine polish.' A type with similar advantages and without some of the drawbacks is that which still contains high sulphur but the phosphorus is normal, and the manganese is increased to about 1½%. This material is bright drawn to dead outer size before the various machine parts are cut off and machined to shape. A further type now much in vogue is one containing as high a sulphur as .2 to .25% with phosphorus about .08%. With specialised control of manufacture and treatment this steel exhibits mechanical properties very little inferior to an ordinary mild steel of the same maximum stress. both in the as rolled and bright drawn conditions, whilst its free cutting properties are undoubtedly of a very high order . . ."

Rolling Mills.

I do not intend to say much concerning rolling for this is largely a mechanical process, although proper temperatures are absolutely essential and must be consistent with the kind of steel to be rolled. Some steels can be rolled satisfactorily at approximately 1,100°C. whereas for free cutting steel the temperature must be in the neighbourhood of 1,200° to 1,250°C.

Acknowledgements.

In the preparation of this paper my thanks are due to the " Davy and United " Engineering Co., Sheffield and the International Construction Co., Kingsway, London, also to my colleagues Mr. Yates, Miss Proctor, and Mr. Peter Farrow for their help.

Discussion

MR. H. C. BULLOCK : As regards your remark that it was general after casting to put steel into a heater in order to keep it at a certain temperature, this procedure may possibly be more economical, but I understand it does not make the best steel. For the better steel is it not desirable that it should cool down and be reheated ?

MR. THORNTON : You are quite right in one respect, certain steels do need to go cold, but with ordinary every-day 28/32 steels it does not matter. If, however, you take .10 to .12% carbon with 3½% nickel, then it needs to be slowly cooled and reheated. Nevertheless, with average bulk quality steel section plates it is not necessary, for you can make tests quite easily, and there is no need to worry about the structure. Up to .18% carbon and sometimes up to .60% carbon on straight carbon steels cooling and reheating are not necessary. I have known .60% carbon steel rails rolled off, the ingots being taken from the soaking pit and put through the cogging mill without cooling and reheating.

MR. BULLOCK : Some time ago we had a lot of trouble with some steel of approximately .65% carbon with .6 to .8% manganese, and I understand it was cast and rolled immediately. When we reforged it the blooms fell in two. We put it down to two reasons, it had either been rolled from the heated condition, or it had not been reduced sufficiently. I believe the trouble was due to not allowing it to cool down before rolling.

MR. THORNTON : The British standard specification for a rail is something like .55 to .60% carbon, .06 sulphur, and .06% phosphorus, with about .8 to 1.25% manganese. You can take such an ingot to and from the soaking pits and roll it without letting it go cold. You can get all the necessary tests including Brinell. Steel makers do not, of course, claim to be more than ordinary individuals, and occasionally some one may do something silly, under which conditions all sorts of unusual things can happen.

MR. R. BROOMHEAD (Section President) who presided : The first time I saw material used without cooling down was when Henry Ford gave us a lecture in Luton. On a film was shown the manufacture of a crown wheel for a back axle. It was the first occasion I had seen an ingot cast, sent along a continuous runway, and cut into smaller ingots in the same heat, put through rolls, and welded ready for machining. On the film the complete operation was shown. I would like to ask if things have changed during the last twenty-five years ; have we got a bit Americanised, or is this something that existed before the last war ?

MR. THORNTON : You were speaking of an ingot, an ingot is a casting. You suggest that Henry Ford took a casting, and parted without forging.

MR. BROOMHEAD : They took the ingot and chipped the ends off. Then it was taken on a continuous runway, cut into smaller ingots in the same heat, put through rolls, and welded ready for machining.

MR. THORNTON : You must, of course, differentiate between a casting and a forging. As soon as an ingot is worked down the size of the crystal becomes smaller. You must consider one as a casting and the other as a forging.

MR. BROOMHEAD : In my early days in Sheffield I had some experience of railway tyre manufacture, and in those days the ingot cast was always allowed to cool down. Has that changed ?

MR. THORNTON : No. I saw ingots cast a few weeks ago. You must allow them to cool down to cut to the length you want for a tyre.

A VISITOR : Is it not the usual practice to normalise that component ? I understood immediately it is rolled or worked it should be normalised to put back the original structure.

MR. BROOMHEAD : The point I was trying to make refers to changes in the manufacture of steel. In the early days these ingots were cast on big steel trucks and left there for three or four days. The ends were chopped off and pressed into little balls before forging. They were hammered in those days and a hole punched in, then put on steel bogeys and inspected for flaws and cracks. Now normalising comes in. That is different altogether from taking a casting, preheating, and then going straight away to finish work.

MR. THORNTON : No, it has not changed. The ingot is cast the desired length and requisite diameter. That has got to be cut off into cheeses, and it must go cold before you can put it into the lathe the part it. These cheeses are put back into a furnace and brought up to forging temperature, and a hole punched in them. That is still being done.

MR. H. J. W. SMITH : The President's reference to the crown wheel for the back axle may be slightly confusing. He probably intended to refer to the fly-wheel ring gear. I have never heard of a crown wheel being rolled round and welded.

MR. BROOMHEAD : Yes, you are quite right.

MR. SHAW : Could you tell us how the grain size is controlled in steels ?

MR. THORNTON : I think control of grain size is a matter of heat control and the final handling of the steel.

MR. H. C. BULLOCK : If you take a bar of given diameter, say 1 in., and with a tensile of about 55 tons. That same bar, when drawn into wire and rolled into wire rope, with not more than

about 75% of the original area, will give about 100% more in tensile.

MR. THORNTON : The wire gets its high tensile due to cold working. If you take a copper bar and hammer it you will get a higher tensile. Cold rolled sheets have to be close annealed.

MR. H. C. BULLOCK : That more or less answers the previous question, that grain size is reduced by rolling.

MR. THORNTON : Yes, you must within limits have ratios as between ingot and finished bar.

MR. BATY : Referring to structural steels, are they now used for motor cars exclusively. Are there no special steels made by different firms, or are these steels used for all purposes ? I am thinking of Rolls Royce. Are their parts made of this structural steel ?

MR. THORNTON : I believe I said in the lecture that I had no hesitation in stating that with a few exceptions, the principal ones being stainless steels and the like, most of the alloy steels could be produced in a basic open hearth furnace. One of the small furnaces shown on the screen is regularly making steels such as nickel-chrome, vanadium, molybdenum, and the like, and was in fact making steels up to a tensile of over 100 tons per square inch. This particular steel plant was making steels for Rolls Royce, Singer, Morris, and Austin cars, I do not know about Vauxhall. Most alloy steels can be made in a basic open hearth furnace, in addition to the ordinary 28/32 under standard No. 15.

MR. H. C. BULLOCK : In the basic method, is the steel reduced to a minimum carbon before the other contents are added, or is it just left and tested first ?

MR. THORNTON : Manganese is added to the ladle during the tapping operation. Nickel is added to the bath, and you get all the nickel back. The quantity of nickel added must be in correct proportion to the weight of steel in the bath. Chrome is added to the bath and you must be certain that the bath is right both as regards slag and carbon before you add chrome. You can put chrome into a bath and lose quite a lot of it if you do not have the bath in the right condition. Molybdenum is pretty certain, you know what the resultant will be to the steel. Chrome is one of the worst alloys to get into your steel and be certain of it. That is the reason stainless steel is made in an electric furnace. If the limit could be 14 to 18 instead of what it is, it would be all right in an open hearth furnace.

MR. GATES : A point which puzzled me was that there were so many specifications for structural and pressure vessel steels, which laid down that the steel must be of acid manufacture. Some manufacturers of these specifications offer acid manufacture and others basic, and the prices and physical tests are practically identical, for

both. What was the reason for the user specifying that the steel must be of acid manufacture ?

MR. THORNTON : To get a good acid steel, you start with a good material. You must have good material and a good steel maker, and then you are certain to get a first class steel which is clean ; it cannot help being clean. If you take basic manufacture you can use almost anything. The steel is made from pig iron with up to 1.8% phosphorus. You do not take any of the phosphorus out of the charge when making steel by the acid process. Phosphorus and sulphur are fatal beyond a certain point in steel. The acid process definitely lends itself to cleanliness if the steel is properly made. The basic process using all sorts of material depends more on the experience of the maker than the acid process. I have seen thousands of tons of steel ranging up to 110 tons tensile for wire, turned out by the basic process. With the same analysis by the acid process you would probably get up to 115 to 120 tons. The conclusion is that the basic might not have quite as clean a structure as the acid.

MR. GATES : That would affect the higher grades. To come down to the 26/32 tons tensile range for structural purposes, it would seem probable that the person drawing up the specification did not quite trust the steel maker to give as good a steel with the basic as with the acid process.

MR. THORNTON : Basic steel is quite suitable for boiler tubes, the tubes in practically all your boilers are made of basic steel. Until you come down to fine limits with such things as gun forgings you are quite safe with basic steel.

MR. VALLENCE : I have a very hazy idea of the subject, but I understand Swedish ore can be used, and that anthracite coal can be used. I take it that this is done when the carbon has become too low. As regards free machining steel, I think if people are prepared to pay for it that is good enough. If the material is good enough for the purpose and the production engineer can get more production by using a free machining steel, I think he has his point.

MR. THORNTON : Anthracite coal is used to increase carbon, and Swedish ore is used to oxydise the bath. As regards the free cutting steel, that is a point, it seems to me too much like the tail wagging the dog. You pay more for your thousands of tons of free cutting steel, and for what reason—production, output. Having got high speed machine tools why not force the issue with the manufacturers of tool steel to give a steel which will enable the producer to get the output he needs when using mild steel at a lower cost than free cutting steel.

MR. VALLENCE : If a certain quality of free cutting steel is good enough for the production engineer why should he use a better quality. If you reduce the quality of steel that is beside the point

to the production engineer. He is buying a quality that is good enough for his particular purpose, and by having it free cutting he is showing a saving in production.

MR. THORNTON : I may be wrong, but I believe usually the man who uses free cutting steel likes to see it come off freely and see it shine, then usually, when he has a nicely finished bar, he puts it out of sight.

MR. BROOMHEAD : Taking into consideration the automatics, and speed in production, you must expect them to prefer free cutt ing steel.

MR. THORNTON : Yes, I expect so.

MR. BROOMHEAD : A lot has been done and is being done with regard to good cutting material, and a cutting tool should be adequate to do the job. You provide the production engineer with a free cutting steel, and he is so happy he does not want to be interfered with. There is a lot being done with regard to free cutting steel. The production engineer to-day sometimes comes up against a steel which he thinks is free cutting until he uses some fairly expensive chasers on it and gets a drag finish or something of that sort. Free cutting steel is also liked for piece work. There is a lot being done with regard to the tool side, but not fast enough as compared with steel production.

MR. THORNTON replying said, I have no right to say that if a man can afford a certain quality he should not have it if he can get it, and if it is suitable for the job.

I am leaving steel making for the moment in order to express views with which many people may not agree. You set an automatic to cut a bolt plus or minus something like $^1/_{1000}$th, yet you cut a hole with $^1/_{32}$ clearance. These are things I do not understand. In my view there is not sufficient motive to do the job properly. You have inspection on inspection. The operator is told by somebody that it has got to be within the limits of something. These limits do not matter because the tolerances in another direction have got to be so much larger to ensure easy erection. Either the bolt should be a fit, or you do not need to go within these fine limits.

MR. BROOMHEAD : I do not think we had better get on the subject of fits and limits.

MR. H. C. BULLOCK : Is there any limit to the length that the ingots are cut off, or does it depend only on how much the top sinks in ?

MR. THORNTON : You can control the ingot. If you have a completely killed ingot, then it sinks in at the top. If you cut off below you are pretty certain of a billet of sound steel. If you take rimmed steel, by virtue of its name, all porocity is round the skin of the ingot.

MR. H. C. BULLOCK : I had in mind a large number of bars of 3% nickel. Most of the bars had a pipe running right through the length of the bar, and most of them had to be scrapped.

MR. THORNTON : It might be a matter of teeming. You must not fill the mould too quickly, and there is a proper rate for teeming according to the quality of the steel. Some ingots are teemed from the top and some from the bottom.

MR. GOVERN : I would like to know why there is such variation of elements in basic figures. In silicon there was a variation of .7 to 1.5%. Also, what is being used for de-sulphurising blast furnaces.

MR. THORNTON : Blast furnaces are in the femine gender and as such they can only be controlled. The difference in silicon is very largely due to temperature. If the furnace is working nice and hot, then you are getting the desired quantity of silicon. If you take a blast furnace working say on Wednesday last, you would have to make an adjustment between then and to-day, because of the big difference in the surrounding atmosphere. In such cases unless you can get some extra coke on the furnace, the furnace chills. The variation in silicon is due to variation of heat in the furnace. You get rid of sulphur with dolomite or limestone.

MR. GOVERN : You arrange burden for desired analysis.

MR. THORNTON : The burden is designed to give the desired analysis. Having fixed the burden the difference in silicon will quite likely be due to the temperature inside the furnace. If you change the burden, however, you will get a change in silicon and must take steps to control it.

MR. GOVERN : If the height of a furnace is 20 ft. or more, that is going to take quite a quantity of pig iron, how do you control it, and how often do you charge it ?

MR. THORNTON : The height of the furnace to the top of the burden may be 70 to 75 ft. You know by practice how long it takes for the material held in the furnace to pass through. You know you have put so much iron with the burden, and you know what the particular burden is. If it is a fast working furnace you might take twelve to sixteen hours, and if it is a slow working furnace it might take twenty-four hours. With a slow working furnace if you put material in at 10-0 o'clock to-night you do not expect to change it until 10-0 o'clock to-morrow night, if the furnace is working right.

MR. GOVERN : How do you take sampling tests ?

MR. THORNTON : The only samples you get are when tapping the furnace. From the beginning of a run until the finish, you will usually get three, one at the beginning, one at the middle, and one at the end. In the whole run you get three samples to give you the average analysis.

MR. GOVERN: Is not a blast furnace controlled more or less by sighting through spy holes?

MR. THORNTON: To some extent.

MR. GOVERN: I take it that the time of tapping depends on the movement of the furnace and the liquid metal in the furnace.

MR. THORNTON: There is another point, in the same way as with the steel maker, the slag is a guide as to the quality of the iron. You take the slag off more often with steel than with iron. If you have a black glassy slag you know the furnace is working cold, and you may alter the temperature of the blast. If the slag comes out very limy, you know the furnace is hot.

The meeting was closed with a vote of thanks to Mr. Thornton for his interesting paper.

WELDING APPLIED TO NON-FERROUS METALS

Paper presented to the Institution, Sydney Section, by E. J. Raymond, Esq.

This paper deals with the welding of copper, bronze, brass, aluminium, and magnesium alloys. The effects of oxygen in copper welding are described in detail, and a technique for flame adjustment is suggested. The advantages of hammering copper welds, when hot or cold, and the effects of annealing are enumerated. The section on welding brass deals with the vapourising of zinc, the effects of zinc oxide, and the absorption of gases which produced porosity and reduce mechanical strength. The welding of "Everdur" in the construction of hot water storage tanks, heaters, pressure vessels, etc., is specially treated. The welding of aluminium is affected considerably by the oxide always present on its surface. The question fluxes for aluminium is also dealt with. The paper closes with a description of the welding of elektron and brief references to the welding of monel and pure nickel. In the discussion following the paper the question of preparation of the weld and temperature testing were mentioned.

THE most important or most widely used non-ferrous metals to which welding is applied are copper, aluminium, and their alloys. I will commence with a short review of the welding of copper and copper alloys. The development of copper welding in comparison with steel has been considerably slower, due to the different technique required, also to the reduced physical properties that were obtained with fusion welds. For many years it was not appreciated that the unsatisfactory results obtained were due to the presence of oxygen in the metal. Electrolytic copper, although containing relatively small amounts of oxygen (0.03 to 0.08) is not suitable for welding, and failure known as oxygen embrittlement invariably results.

The metallurgical explanation is that oxygen unites with copper to form a compound known as cuprous oxide, which in turn unites with the copper to form a eutectic which is hard and brittle. This cuprous oxide is present in the form of small particles which, as a result of the forming and annealing operations during manufacture, are distributed within the grains of the metal. Therefore, in well made copper, the oxide is uniformly distributed within the grains rather than along the boundaries.

Cuprous oxide is soluble in liquid copper but only slightly soluble in the solid metal. The cuprous oxide which is dissolved in the liquid copper separates out as the molten metal cools down and

solidifies. The oxide forms a network around the grains and renders the material brittle. By collecting at the grain boundaries as films of the copper cuprous oxide eutectic instead of remaining as small spheroids within the grains, the cuprous oxide causes a reduction in both tensile strenth and ductility. This occurs when copper is heated to a temperature above the melting point of the eutectic 1,065°C. but below the melting point of the copper itself, viz. 1,083°C.

The second weakening effect caused by the cuprous oxide is brought about by the hydrogen from the flame diffusing into the hot copper, which reduces the cuprous oxide, producing sponge copper and steam in the process. The steam cannot diffuse outwardly, hence a high pressure is built up within the metal, which produces minute fissures or porosity in the bond between the grains. This effect is pronounced at temperatures above 700°C.

To overcome these difficulties a weldable or deoxidised copper has been produced which, although it is manufactured in the usual way, contains deoxidising agents which combine with the oxygen in the copper and so prevent the formation of the cuprous oxide and the hydrogen attack. Phosphorus and silicon are the principal deoxidisers. Modern deoxidised coppers are readily obtainable and should always be used for fusion welding ; the electrical and thermal properties are slightly lower than those of non-deoxidised metals.

In gas welding deoxidised copper it is necessary to use a deoxidised copper filler rod—which generally contains an additional alloying element—to lower the melting point of the rod slightly and reduce the grain size of the weld metal. Silver or manganese are most commonly used.

There is no great difficulty in gas welding copper, and with experience, copper can be handled and welded as easily as steel. Of recent years a good deal of attention has been focussed on the welding of locomotive copper fire boxes. The copper usually employed contains approximately .5% of arsenic, and is known as arsenical copper. Arsenical copper, however, is not an oxidised copper and segregation of the cuprous oxide takes place exactly in the same way as with electrolytic copper. Mainly due to the high cooling stresses of the weld metal, a special welding technique is adopted. Heavy steel backing strips are placed under the weld and welding is carried out in short runs of about two to three inches in length, which are hammered hot before further runs are made. Hammering, in addition to stress relieving, also refines the crystal structure and improves the physical properties of the weld.

Regarding the blowpipe flame adjustment, it is necessary to work with an absolutely neutral flame. If there is an excess of oxygen in the flame there will be an increased tendency towards the formation of copper oxide, and a brittle weld will be obtained.

If there is a preponderance of reducing gases in the flame, that is to say, if an excess of acetylene is used, there will be even more danger of a defective weld, because copper, when in the molten and plastic stage, readily dissolves gases. It will dissolve hydrogen with the greatest ease, and the hydrogen will react with any oxygen that there may be in the copper to form water vapour. This will escape from the molten metal in the form of bubbles, and so produce a porous weld. Alternatively, the gases will be trapped within the metal and give rise to the danger of brittleness and faulty structure.

The best technique of flame adjustment to adopt is that used for stainless steel. A flame having an excess of acetylene should first be obtained, and then the acetylene supply should be gradually reduced until there is the merest haze of acetylene around the centre cone of the blowpipe flame. In this condition, the flame is definitely not oxidising and is as near neutral as it is possible to get.

After Treatment of Welds.

The treatment of welds during and immediately after copper welding is a matter open to considerable discussion. The technique applied is dependent upon the arrangement of the job, the ability of the welders and the type of copper employed. It can be said, in general, that hammering the weld is advantageous in most cases. Usually, it should be hammered whilst the copper is still hot and at a temperature above 600°C. The hammering should be light, and great care should be taken not to damage the surface. Hammering has many advantages. It prevents excessive grain growth in the copper surrounding the weld metal, it breaks up the copper cuprous oxide eutectic preventing it from segregating at grain boundaries, and it hardens and strengthens the surface of the weld. This treatment is recommended when copper is of the non-deoxidised variety.

In some cases it is an advantage to hammer the weld when it is cold. The cold work performed on the copper is very advantageous in strengthening the mechanical properties of the metal and in consolidating the surface.

The question of subsequently annealing the metal is not quite so important. The annealing temperature used should be in the range 550° to 650°C., but in the majority of cases the shape of the article precludes such treatment because there will be a danger of collapse. For small articles such treatment is useful but for larger structures it is hardly feasible. The effect of annealing is to increase the uniformity of the metal in and around the weld.

Copper has a very large field of application in industry to-day. It is used extensively in the chemical, brewing, and textile trades, and welding provides the ideal method of fabrication. Welded joints, when correctly carried out with the best technique, welding

rods and welding fluxes, present many advantages over other forms of joint. The weld is homogeneous, and hence there need be no fear of subsequent corrosion, due to galvanic action. The joint is smooth and uniform with the sheet, thus eliminating the possibility of the entrapment of solid particles or corrosive matter, and further, welded joints are leak-proof and pressure-tight. There is no danger of unequal expansion and contraction stresses being set up due to the effect of heat or cold, and finally the weld is neat and pleasant in appearance. There is no doubt that, properly applied, copper welding is capable of replacing with advantage other types of joint.

Brass and Bronze.

There is a very large collection of alloys used in industry which come under the heading of brass and bronze, and the subject has been further complicated by the many trade names and proprietary brands of this metal. Consequently, the welder will often experience difficulty in designating a metal by its proprietary name alone, which often gives no indication of the alloy's weldability.

The principal constituent of brass and bronze is copper. Brass is an alloy containing copper and zinc in varying amounts, whilst bronze refers to a metal containing copper and tin ; other elements may be present, such as silicon, nickel, manganese, iron, aluminium, lead, etc., in small percentages, but the principal constituents are copper and zinc or copper and tin. Many of the commercial alloys which are called bronzes are really brasses, so that care should be exercised before attempting to weld a metal which is referred to by a proprietary name. Under the blowpipe flame, brass fumes more readily than does bronze, on account of the presence of zinc in the former.

The one feature which concerns the operator most in making a fusion weld in brass is the tendency for the zinc to vaporise from the molten metal. Zinc melts at about 419°C. whereas copper melts at 1,083°C. approximately, which means that, if any overheating occurs, the zinc will boil and come away from the molten metal in the form of vapour. There will naturally be a loss of the zinc constituent, the resultant weld will be porous, and the surrounding metal and atmosphere will be covered with a white powder, consisting of zinc oxide. This oxide is injurious and should not be inhaled.

The second difficulty is that the zinc, without even volatilising, becomes oxidised when heated in the presence of air. This means that a layer of zinc oxide will be formed on the weld and will interfere with the production of a sound joint.

A third important point is the ease with which copper and copper alloys absorb gases when molten. Brasses do not absorb gases quite so easily as does pure copper, but they do absorb gases to a

certain extent and, if this takes place, porous welds will be produced having little or no mechanical strength. This reaction of the zinc is common to all brasses but is very pronounced with the yellow extruded sections used for window frame construction, sometimes called architectural bronzes. These alloys also contain lead, tin, or aluminium, which further complicates the position and renders welding even more difficult. Lead, for example, is soluble up to 0.7% and will cause increased difficulty in welding, as this percentage increases. Brasses with a lead content of 5% are practically impossible to weld.

It was realised many years ago that film forming elements could be used to prevent the zinc from vapourising. These films may be developed in several ways, by the addition of a suitable film forming element to the brass alloy, by the use of a suitable element in the flux, and by a suitable adjustment of the blowpipe atmosphere. Fluxes alone are also of little use. The only satisfactory method is by the adjustment of the blowpipe atmosphere or, as it is more commonly known, the use of an oxidising flame. Just to describe the flame purely as oxidising is not sufficient, as the purpose and the degree of excess oxygen required must be understood. One particular flame adjustment is not satisfactory for welding all the alloys in this series.

The purpose of the oxidising flame is to provide a skin or film of oxide upon the surface of the molten puddle having a surface tension of greater strength than the vapour pressure of the volatile zinc constituent, thus preventing further oxidation of the zinc. Satisfactory welds can be made if the correct procedure is adopted. In addition to the usual prepration, the most important consideration is that of flame adjustment. It has been found by experience that the best results are obtained with an oxidising flame ; neutral or carburising flames should not be used. Particular attention must be paid to this point because, although the flame is described as oxidising, it is not produced by turning on an excess of oxygen to the neutral flame.

The flame is first adjusted by regulating the gas control valves to give a normal neutral flame, and then the acetylene supply is reduced. This will produce a soft oxidising flame. It is recommended to use a larger size blowpipe tip for the welding of brass than would be used for a similar thickness of steel. The exact amount of excess oxygen required in the flame varies according to the zinc content of the brass. The correct flame adjustment is best determined by making a preliminary test on a piece of scrap metal of similar composition to that being welded ; the scrap metal should be melted and the extent of the fuming observed. The acetylene should then be decreased until fuming ceases. In this condition, no blowholes

should be produced in the fused metal but, should any appear, the acetylene must be reduced still further.

Everdur.

Although copper has been used for many years in the construction of hot water storage tanks, bath heaters, pressure vessels, etc., it is relatively weak in the annealed or softened condition, consequently the material does not possess the necessary physical properties required by modern services. A metal termed Everdur, a copper-silicon-manganese alloy possessing the strength of mild steel, with excellent corrosion-resisting properties, high fatigue limit, and weldability, is rapidly replacing copper for the services mentioned. It is immune to rust and is better than copper in resistance to other forms of corrosion. Everdur contains approximately 96% copper, 3% silicon, and 1% manganese. In welding, the usual single or double vee butt joints are used ; flux is not absolutely necessary but the flowing qualities of the metal are improved by its use.

Everdur should be welded as rapidly as possible to keep the shrinkage stresses in the red hot metal as low as possible. The quicker the metal is solidified the more uniform will be the cold metal and the finer the structure. On heavy material, $\frac{3}{8}$ in. and over, the double layer or two layer method of welding can be employed to advantage ; a single vee joint of 80 to 90° being preferable. The first run is made upon the bottom of the vee, which is only partially filled ; the entire seam is completed in this way before the second run is made. The second layer or run is deposited immediately upon the first run without additional preparation. Where maximum ductility and strength are required the weld metal may be peened and locally annealed at a dull red temperature (about 1112°F.). Regarding flame adjustment, a slightly oxidising flame should be used in order to secure maximum heat concentration with a maximum rapidity of welding.

Aluminium.

The greatest difficulty in welding aluminium and its alloys is that of removing the oxide which is always present on the surface of the metal and which impedes the flowing together of the molten edges. The melting point of this oxide is approximately 2,745°C., whereas the parent metal melts at temperatures between 600 and 700°C. This oxide is very refractory ; its specific gravity is greater than that of the molten aluminium, so that it is imperative that it be removed and not distributed throughout the weld metal. This is generally carried out by means of a flux which, at the high temperature of the oxy-acetylene flame, rapidly combines with the oxide and dissolves it, at the same time forming a protective layer

upon the surface. The method of using flux depends upon the amount and type of welding done. The flux may be used dry or as a paste mixed with water and brushed on the job and the rod. It should be used sparingly in order to avoid flux inclusions. Another method is to dip the heated rod in flux and melt the tuft of flux down the rod to form a thick varnish along the rod for about 6 in. Since this flux readily absorbs moisture, the container must be kept closed when not in use.

A good deal of sheet aluminium welding is being carried out at the present time in connection with aircraft construction, and one of the Air Force requirements is that a bead of weld metal or ripple must appear on the underside, thus ensuring full penetration of the weld through the sheet. Liquid flux is fast coming into favour for this class of work, as, by its use a fully developed bead on the under side of the weld is readily made. It is impossible to weld sheet aluminium without the aid of flux.

Normally, sheet aluminium up to $\frac{1}{4}$ in. thickness is welded from one side using a single vee butt weld with an included angle fo 90°, but for plates in excess of $\frac{1}{4}$ in. the two-operated vertical method is employed ; the operators are placed on either side of the plate and a double vee joint is used. For aircraft and some commercial construction, a filler rod of pure aluminium is used, but where colour match is not detrimental, a silicon aluminium rod of 5 to 10% may be used to advantage. The addition of silicon lowers the melting point and increases the fluidity—which are important considerations in repair work.

Aluminium castings are readily weldable, and the process is generally the same as for the pure sheet metal, with the exception that, due to the greater thickness, puddling of the weld metal is often used ; preheating is desirable when repairing crank cases and similar objects, since castings are less ductile than sheet aluminium and local contraction stressing must be avoided.

The majority of common and strong aluminium alloys are readily weldable, but one notable exception calls for special mention—that is an alloy of aluminium-copper-magnesium and manganese, generally known as duralumin. This alloy is principally used in structural work and is supplied in wrought form or sheets ; in these conditions the alloy has been subjected to considerable mechanical work which has brought about an entirely different physical condition from the original metal as cast. In addition, the material is subjected to a process known as ageing, which extends over several days. As it is impossible to approximate even within fairly wide limits, the mechanical strength and physical properties of the parent metal, the welding of Duralumin is not recommended or considered practical.

Magnesium Alloys.

One of the most important light metals which has been recently introduced to industry is the magnesium alloys, the most popular of which is elektron, and, due to their low weight and high strength-to-weight ratio accompanied by ease of working, they have been readily accepted by the aircraft and transport industries. The elektron alloys comprise a fairly wide range of compositions, the principal element being magnesium, which runs between 86 and 92%, with the addition of small amounts of aluminium, zinc, manganese, copper and silicon, according to the requirements of the alloy. The composition of the casting alloys is somewhat different from that of the wrought alloys—which necessitates a different welding procedure. The welding rods for casting alloys are designated by the prefix AZ102, and the rods for wrought alloys AM503.

The general procedure adopted for the welding of aluminium castings is employed—that is, the casting must be thoroughly cleaned and carefully preheated. Elektron castings should not be preheated above the temperature of 250 to 300°C. Owing to the risk of complete collapse, which may occur where the temperature is raised too quickly, it is not advisable to use ordinary preheating furnaces. It is necessary to use a special flux; aluminium flux is not suitable. The flux is very corrosive, consequently it should be used sparingly and all traces of flux removed after welding; areas which are inaccessible to cleaning should be vented in some way to ensure that the flux is not entrapped. After welding, the weld and adjacent areas should be scrubbed with hot soapy water. Regarding the ignition hazard, there is practically no danger at the welding temperature, but care must be taken not to overheat; the melting point of the elektron alloys varies between 600 and 645°C.; the thermal conductivity is about one-third that of copper.

One of the big advantages of elektron over aluminium alloys is its weldability. This property is of great importance in sheet and drawn forms, as it leads to greater simplicity of design over a corresponding riveted structure.

Welding of sheet or tube is a fairly simple operation. Due to the susceptibility of flux corrosion, butt joints are employed; lap joints should not be used. Hammering of a welded seam improves its strength slightly, but is not necessary. Annealing is unnecessary, and age hardening does not occur. The principle of manufacture of tanks which require internal bracing or stiffening is to build up the tanks of strips of sheet bent to the periphery of the tank and to join these seams by welding to the flanges of an extruded T section, the web of which is inside the finished tank, and to which bracing members or bulkheads are riveted. The method of construction is to cut, bend and weld into a hoop each strip or section, and then

to seam-weld these together. The internal structure is next riveted up and the end caps finally welded in position. After each seam weld buckling is removed from the sheet by hammering.

To prevent corrosion from the action of water inclusions in tetraethyl-lead fuels, a standard corrosion inhibitor consisting of a cast cage containing a charge of lead salts is welded into the sheet.

Monel.

Monel is a nickel copper alloy containing about 67% nickel and 30% copper and 3% of other elements consisting partly of iron, manganese, silicon and carbon which are introduced in the refining process. Monel is readily weldable by the oxy-acetylene process, either in the sheet or the cast form ; it can also be welded to almost any common metal or alloy.

Pure Nickel.

On account of its corrosion-resisting properties, pure nickel finds a certain field of usefulness in modern food processing plants, etc. It is readily weldable by the usual methods, a carburising flame being employed. The end of the filler rod and the molten puddle should be kept within the outer envelope of the flame to prevent surface oxidation. The nickel and high nickel alloys should on no account be puddled or boiled, as this practice tends to burn out the deoxidisers which are important ingredients of these alloys, although present in very small quantities. The molten metal must be kept quiet during the welding operation. After welding, the nickel weld metal should be lightly hammered or peened to improve its physical properties.

Discussion

MR. NASSER : Is flux used in the welding of locomotive fireboxes ?

MR. RAYMOND : No, flux is not used on copper, which flows readily under the flame. It is necessary to use two blowpipes when welding copper fireboxes, to enable the metal to be quickly brought to the welding temperature. One blowpipe is employed in welding, the other assists in keeping the copper at the correct temperature, both welders working from the one side. When repairing cracks in tube plates, the welders are placed on both sides of the plate —one in the firebox and the other on the tube side of the plate. The weld is then made from both sides, using a double-vee preparation. The welders have to be specially trained, as welding is difficult.

MR. SWEET : In the Bristol Aircraft Co., when welding an elektron crank case, I know of a man who tests the temperature by putting a piece of soap into it. The Americans have a special technique, and I would like to know if it has ever been used in Australia.

MR. RAYMOND : I am pleased to hear about the soap. I know there are various methods of determining the correct temperature, mostly brought about by accident. Some people use a pine stick.

Everdur is a copper silicon manganese alloy and is readily weldable by any process, and in these days of high pressures and high temperatures Everdur will generally be more satisfactory than copper. Everdur is being used to a great extent throughout the world but it is only just finding its way into Australia.

MR. OGDEN : Has anything been done with arc welding of copper in Australia ?

MR. RAYMOND : No, sir ; there has been very little progress so far on the class of work to which I have referred (loco copper firebox welding). A good number of experiments have been made in America, but I do not think that it has reached the stage of being a serious competitor to the oxy-acetylene process in so far as firebox welding is concerned. Carbon arc welding is used to some extent by the Hobart Co. of America.

MR. CLAPSHAW : What is the idea of allowing each section of the weld to cool ?

MR. RAYMOND : Complete contraction of each section is desired. If hammering were not employed, the metal would crack. Hammering is used to improve the physical properties and to stretch the weld metal.

MR. NASSER : Do you allow it to cool off normally ?

MR. RAYMOND : Yes, it is quite a long job. Actually the fireboxes are repaired without much dismantling, so in the end it is a profitable job.

MR. NASSER: Referring to the matter of testing the heat, I do it with a safety match.

MR. RAYMOND: Yes, I believe it can be done.

MR. CLAPSHAW: I have heard that some German planes made of magnesium readily ignite when they are hit by tracer bullets. Is that so?

MR. RAYMOND: It does ignite readily, but only at a high temperature. The welding temperature must be hept low, otherwise there is a danger of ignition. But when you reach the stage where ignition is likely to happen, the metal simply collapses. Possibly the bullet in striking the casting will raise the temperature sufficiently to bring it near the ignition point.

MR. Nasser: Why is it that in aircraft production they prefer the oxy-acetylene method to the electric arc?

MR. RAYMOND: The metallic arc process is used to some extent in aircraft fabrication to-day, but it depends entirely on the class of work and the thickness of the metal. For ordinary tubing the oxy-acetylene process is used, and in other classes of work of a heavier nature, arc welding may be employed; but the oxy-acetylene process is principally employed in England and Australia for all welding. The arc welding of aluminium is quite practical to-day, but not on thin sheets such as are used in aircraft construction.

The meeting closed with a vote of thanks proposed by Mr. McPhee.

THE SUPPLY AND MANUFACTURE OF JIGS, TOOLS, GAUGES, AND EQUIPMENT FOR WAR PRODUCTION PROGRAMMES

Memorandum by the War Emergency Committee of the Institution, presented to the Industrial Capacity Committee of the Production Executive of the Cabinet, January 22, 1941.

SIRS,

ON September 2, 1940, the Institution of Production Engineers presented to the Production Council a Memorandum on War Production Problems. This Memorandum will have served as an introduction for the Institution, the War Emergency Committee of which now wishes to present to you a further Memorandum. The particular subject which has been engaging our attention for a long time and which we now wish to present to you concerns the situation with regard to supply and capacity for the manufacture of jigs, tools, gauges and equipment, and we wish to recommend—

THAT URGENT CONSIDERATION SHOULD BE GIVEN TO MEANS FOR INCREASING THE NATIONAL CAPACITY FOR THE MANUFACTURE OF JIGS, TOOLS, GAUGES AND EQUIPMENT

through various means which are discussed in the body of this memorandum.

The inception and carrying through of a production programme for the manufacture of any designed article or mechanism is largely dependent upon these major factors: Availability of orders, availability of factory space, availability of materials, availability of machinery, availability of jigs, tools, gauges and equipment, availability of labour.

Efficient production can only be obtained if each of these items is available in the right quantities at the right time. The non-availability or short supply of any one of them materially affects the efficient use of the remainder with consequent loss of production.

We wish to draw attention to the facilities for the manufacture and supply of jigs, tools and gauges and equipment which, in our opinion, is not at present receiving the attention which its importance to the war effort of the country demands. This opinion is not based

solely on the observation and experience of the members of the Committee, but is confirmed by the experience of many members of the Institution holding high executive positions in industry.

The term jigs, tools, gauges and equipment covers a very wide range and can roughly be divided into two main categories as follows :—

(*a*) Those items which are of standard character and can in a normal way be bought from stock or upon short delivery and which can usually be selected from standard sheets, such as drills, taps, dies, reamers, milling cutters, standard plug and ring gauges, screw gauges, gap gauges, etc.

(*b*) Items of a non-standard character which are particular to a given product or process and which must be designed and made to customer requirements. These items cover an infinitely variable field, depending not only upon variations of product but also upon the particular method of production adopted by each manufacturer.

It is obvious that those items in Category A present a much simpler problem than those in Category B, inasmuch as they are of a standard nature and are manufactured in reasonably large volume and can, in extremity, be purchased from abroad. Such items can normally be made for stock in the assurance that they will in time be absorbed by industry.

On the contrary, those items in Category B can rarely be manufactured in quantities since they are essentially related to only a single product and are, therefore, subject to changes on demand, changes of design or changes in manufacturing processes.

The Present Position

We cannot claim to have a complete knowledge either of the measured capacity in the country for the production of jigs, tools and gauges or of the load of requirements which can be expected. There is probably no field in which it is more difficult to speak with authority on the capacity of industry than the small tool field. We know, however, without any doubt whatever that many items in Category A are in short supply, that delivery promises are extremely difficult to obtain and when obtained are very rarely maintained. This remark applies with particular emphasis to articles like ground thread taps or screw gauges, and the former are essential for use in the manufacture of articles from certain of the high tensile materials, or alternatively in order to produce accurate finish on a wide range of armament products.

We know also that the order books of practically every tool manufacturing firm of repute are full for the next six months, and this means that unless firms expecting new contracts can manufacture all the special tools and equipment required in their own tool-

rooms, tooling cannot be available to commence production for six to nine months after the date upon which a firm has completed the design and specification of such equipment. The reaction of this upon the delivery dates for new Service requirements is obvious.

It is characteristic of war-time production that industry experiences a demand for a far higher volume of new tooling than in peace time and, under these conditions, the relationship between the country's capacity for making tools and its capacity for operating these tools and producing finished products assumes a new balance. When coupled with the greater urgency surrounding production of the war-time product the necessity for a planned increase in the capacity of our tool-making facilities becomes an obvious necessity.

EFFECT OF THE SHORTAGE OF TOOLS UPON PRODUCTION

Effect on Production Planning.

The knowledge of the long delivery position for special tools and equipment must react upon the planned methods of production. The tendency must inevitably be to adopt methods which reduce the requirements for such tools and equipment to the minimum, irrespective of the efficiency of such methods and the ultimate cost of production. The result is a definite loss of production from a given amount of factory space, machinery and labour.

Effect on Labour Situation.

The non-availability of adequate supplies of tools and equipment result in an unnecessary demand for skilled labour. Work which, if properly equipped, could be carried out by semi-skilled or unskilled labour must be carried out by high-grade skilled labour and, in many cases, also entails the use of a high grade of machinery. As a simple instance, a job which requires three holes to be produced in the same plane to a size tolerance of $\begin{matrix}+.001 \text{ in.} \\ -.0005 \text{ in.}\end{matrix}$ and to a chordal tolerance of $\begin{matrix}+.002 \text{ in.} \\ -.002 \text{ in.}\end{matrix}$ would be a simple job for semi-skilled labour using a drilling machine and the appropriate tools. In the absence of the proper tooling equipment the job becomes one for a skilled man either on a jig boring machine, a milling machine or a lathe, and the production time for piece may be anything from 10 to 50 times that taken by the semi-skilled man operating the cheaper machine.

The shortage of high-grade skilled labour is already a major problem and is itself one of the principal obstacles to the adequate supply of tools and equipment. The use of such labour on tasks which could be performed by properly equipped semi-skilled labour is to intensify the shortage. Furthermore, the proposal to increase the

labour forces on war production by the large-scale absorption of unskilled men and women is totally dependent upon the solution of the problem of providing ample supplies of tools and equipment.

Effect on the Utilisation of Machine Tools.

Machine tools can be described as tool users or tool carriers, their function being the scientific application of tools to materials. The efficient use of machine tools is totally dependent upon the supply of the proper tooling and equipment to go with them.

Machines of a simple type operated by semi-skilled or unskilled labour with the assistance of proper equipment are even capable of producing and reproducing the most accurate work more consistently as well as more rapidly than more complicated and costly machines operated by skilled labour but lacking the same equipment.

Cumulative Effect on Production.

The lack of tools and equipment means that larger numbers of machine tools of a more costly type are necessary to produce a given amount of the product, that these machines must be operated by a higher grade of labour than would be necessary were that equipment available and that the larger number of machines must occupy more factory space. Cumulative effects of these trends on production are to limit output and increase costs.

We feel, too, that the situation is likely to be further aggravated by the increasing number of machine tools now being provided from both home and overseas sources since all these machines must be tooled and equipped before they can be brought into production, and when in production will further increase the volume of perishable tool replacement which forms no small portion of the total output of the tool industry.

The expansion of took-making facilities has not, in our view, kept in step with this increase in machine tools.

Remedial Action.

The above remarks should sufficiently illustrate the vital nature of the tool gauge and equipment manufacturing section of the engineering industry, and the fact that the present operative capacity is insufficient to meet the existing load of requirements must be taken as an indication that it cannot be left to private enterprise to provide the extra tool-making capacity necessary to enable new products to be brought to the production stage in a reasonable time period.

In the absence of complete knowledge of capacity and requirements which can only be obtained by Government action, the following constructive suggestions are put forward as bases upon which remedial action be formulated.

(*a*) The vital nature of the tool making industry should be recognised, and it should be accorded a high priority in the allocation of labour, material, and machinery.

(*b*) It is considered to be essential that the Government should itself subsidise the expansion of manufacturing space and equipment of efficient tool manufacturing firms. In any such programme it is considered to be generally necessary that extensions, if not to existing buildings themselves, should at least be sufficiently close so that full use can be made of the same executive personnel of whom there is a shortage.

(*c*) It is considered that tool manufacturing firms who are not properly equipped or who are not financially able to utilise plant and labour which they have available should come under Government control, so that their efficiency can be assured, after which they, too, should be suitably extended.

(*d*) It is recommended that the Government should insist that all firms having their own tool rooms should fully man such tool rooms with a view to meeting, so far as possible, their own requirements for tools and also to rendering as much assistance as possible to the tool making effort of the country by using all surplus tool production capacity for the manufacture of tools and equipment for extraneous sources. It is recommended that, in selected instances, the tool making facilities of such firms should also be extended with the help of Government finance.

(*e*) Attention is drawn to the fact that a number of firms in the *machine tool* trade are in grave danger of becoming idle and some cannot see a full load of work extending beyond three months. Such firms are now actively touting for orders. Whatever action may be contemplated to correct this position, it is now too late to avoid serious gaps in production for these firms, all of whom would be ideally suited for the manufacture of many of the much needed items of equipment coming under the title of this memorandum. It is recommended that arrangements should be made for idle machine tool capacity to be used in this way.

(*f*) If the above recommended steps fail to produce adequate extension of tool making capacity, it is then recommended that the setting up of "shadow" tool making organisations should be considered. Such organisations would be controlled on behalf of the Government by firms having specialised experience in tool and equipment manufacture.

(*g*) It is recommended, in view of the highly technical character of this problem, that a Panel should be set up representative

of tool manufacturing firms, tool consumers, and Government Departments with powers to gather the basic information and statistics on this subject. This Panel should make a census of existing tool production capacity both of a private and of a public character with a view to the harnessing of the whole of such capacity in the national interest. It should also assess a forward tool production requirement so that steps could be taken on a sound basis to increase sources of supply in step with potential demands. *The setting up of such a Panel should not delay immediate action being taken along the lines suggested in the first three of the previous recommendations.*

(*h*) It is recommended that when Government Departments are issuing contracts to new sources of supply the contractors should be put into touch with other existing sources of supply for the same product. It would then be possible for advantage to be taken of tool and equipment drawings already produced and possibly for the purchase of duplicate equipment from the same source. Such action would save the cost of patterns, would frequently enable production to be started, while it would often be possible for the firms in conjunction with one another to arrange for the combined ordering of replacements, which will often prove a cheaper and more convenient arrangement.

Conclusion.

The Institution of Production Engineers is prepared to give all the assistance in its power towards the solution of this problem which it believes to be one of vital national urgency. Its members can speak with particular knowledge and emphasis on this subject, and have an intimate and detailed knowledge of this phase of our national effort.

The Committee requests that facilities be granted for a small deputation to wait upon you so that further particulars of our suggestions may be given.

J. E. Blackshaw, Engineer and General Manager, G. D. Peters & Co. Ltd., Slough.

H. le Cheminant, Group Manager, Parnall Aircraft, Ltd., Tolworth.

G. H. Hales, Engineer and Managing Director, Geo. H. Hales Machine Tool Co. Ltd.

F. W. Halliwell, Engineer and Managing Director, Arnott & Harrison, Ltd.

B. C. JENKINS, recently Production Engineer, Vauxhall Motors, Ltd., New Southgate.

N. V. KIPPING, Works Manager, Standard Telephones and Cables, Ltd.

W. S. PUCKEY, Works Manager, Hoover, Ltd.

J. D. SCAIFE, Engineer and Managing Director, John Lund, Ltd.

January 22, 1941.